ULDB
Systems
Definition
Review

ULDB Recovery Systems

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Objectives

- Decelerate payload from termination to safe impact
- Provide impact attenuation for land recovery
- Provide flotation for water recovery
- Provide location aids for remote areas

Descent

Current method is unfurled flat circular chute in flight train

+ Simple design
+ Low risk
+ Inexpensive
– Impact accuracy ~3.22 km radius
– *Unacceptable material degradation due to environmental exposure*

- Weight: 215 kg   Cost: $12,566

Descent Alternatives

- **Enveloped Flat Circular**

  Unfurled chute in flight train, enveloped in protective material

- **Packed Flat Circular**

  Better material protection, but more complicated

- **Packed Two-Stage System**

  Improved accuracy via quick first-stage descent

- **Guided Parafoil**

  Highest impact accuracy, but very complicated and expensive

Descent Alternatives

Enveloped Flat Circular

+ Simple
+ Low deployment risk
+ Slightly lower opening shock load
+ Small weight penalty
– More expensive
– No improvement on impact accuracy
– Potential problem with canopy/sleeve friction
– Untried design
• Weight: ~238 kg   Cost: ~$17,070

Descent Alternatives

Packed Flat Circular

+ Inexpensive
+ Small weight penalty
+ Lower opening shock load
+ Common design

– Higher complexity

– No improvement on impact accuracy

- Weight: ~218 kg Cost: ~$14,070

Descent Alternatives

Packed Two-Stage System

+ Small weight penalty
+ Lower opening shock load
+ Impact accuracy improved to ~400 m radius
+ Common design
– More expensive
– Higher complexity
• Weight: ~229 kg   Cost: ~$18,070

ULDB Systems Definition Review

Recovery Systems

Descent Alternatives

Guided Parafoil

+ Small weight penalty
+ Lower opening shock load
+ Impact accuracy improved to 200 m radius
– Initially much more expensive
– Much higher complexity
– New technology
- Weight: ~227 kg
- Initial cost: ~$130,000 Refurb: ~$10-15K

ULDB
Systems
Definition
Review

Recovery
Systems

Descent Alternatives

Trade Study						
	Maximum	Flat Circular As Is	Enveloped Flat Circular	Packed Flat Circular	2-Stage System	GPS-Guided Parafoil
Performance	10	5	6	6	8	9
Weight	10	8	6	8	7	7
Size	5	3	3	4	4	3
Cost	8	7	4	6	5	2
Schedule	8	8	7	7	6	5
Power	5	5	5	5	4	3
Interfaces	5	4	4	3	3	2
Hazmat	5	5	5	5	4	3
Risk	10	9	6	7	6	4
Total	**66**	**54**	**46**	**51**	**47**	**38**

Packed flat circular scores higher, if greater impact accuracy required then use packed two-stage system

ULDB
Systems
Definition
Review

Recovery
Systems

Descent Alternatives

Characteristics					
	Flat Circular As Is	Enveloped Flat Circular	Packed Flat Circular	2-Stage System	GPS-Guided Parafoil
Weight, kg	215	238	218	229	227
Cost, $	12,566	17,070	14,070	18,070	130,000
Impact Radius, km	3.2	3.2	3.2	0.4	0.2
Max Load, g	7	7	7	7.4	3

Opening Load Attenuator

- Opening shock of parachute imparts high *g*-levels on payload
- Balloon Branch has device that dissipates shock energy via ripping of stitches in flight-train webbing
- Ground tested & test-flown
- Use as needed
- Weight: 16-31 kg   Cost: $5,500

Land Impact Options

PASSIVE ATTENUATION DEVICES

- **Crush Pads**

  Cardboard & styrofoam; simple, cheap, balloon-qualified; environmental exposure effects unknown

- **Aluminum Honeycomb Pads**

  Rocket-qualified, higher absorbed energy/cu-ft, higher cost ($60/cu-ft)

ACTIVE ATTENUATION DEVICES

- **Air Bags**

  Compact, expensive, higher risk, level of effort; double-duty as water impact bags?

ULDB
Systems
Definition
Review

Recovery
Systems

Land Impact Options

Trade Study				
	Maximum	Crush Pads	Honeycomb	Air Bags
Performance	10	10	10	9
Weight	10	9	9	7
Size	5	3	4	4
Cost	8	7	6	4
Schedule	8	8	8	5
Power	5	5	5	4
Interfaces	5	4	4	3
Hazmat	5	5	5	4
Risk	10	9	9	7
Total	**66**	**60**	**60**	**47**

No clear winner between simple solutions of crush pads and aluminum honeycomb

Water Impact Options

PASSIVE FLOTATION DEVICES

- **Sealed Structural Volume**

  Structural tubing sealed to provide positive buoyancy

- **Foam-Filled Structural Volume**

  Replace air with foam; lower risk than sealed volume, slightly heavier

- **Strap-On Floats**

  Off-the-shelf floats/buoys strapped to structural members; fewer mechanical interface problems

Water Impact Options

ACTIVE FLOTATION DEVICES

- **Structure-Mounted Inflatable**

  Deployable air bag attached to gondola; compact, higher risk, higher cost

- **Tethered Inflatable Buoy**

  Deployable air bag tethered to submerged gondola; semi-qualified on rocket payloads, fewer mechanical interface issues

Water Impact Options

Trade Study						
	Maximum	Sealed Volume	Foam-Filled Structure	Strap-On Floats	Hard-Mount Inflatable	Tethered Inflatable
Performance	10	10	10	10	10	10
Weight	10	10	9	9	8	8
Size	5	3	3	3	4	4
Cost	8	7	6	6	4	4
Schedule	8	7	8	8	5	5
Power	5	5	5	5	4	4
Interfaces	5	2	2	3	4	5
Hazmat	5	5	5	5	4	4
Risk	10	7	10	10	7	7
Total	**66**	**56**	**58**	**59**	**50**	**51**

Strap-on floats win due to ease of interface

Location Aids

- In case of unplanned termination, need location aids for recovery in remote areas
- Sounding Rocket Program has successfully used DF radio beacons, ARGOS transmitters, strobe lights

	ARGOS	**164.X MHz**	**242.0 MHz**
Xmitter Cost, $	3,380	500	1,711
Xmitter Weight, g	273	64	65
Range, km	N/A	32	160
Signal Life, days/kg of batteries	7.0	2,897	13.2

Additional Systems

Options being persued

- Dropsonde development

  Deployable GPS sonde to give “near real time” wind measurements for descent vector determination

- Automated chute cut-away

  Investigation of approach to automatically cut chute after Earth impact

Recommendation

- Packed flat circular parachute system
- Opening shock load attenuator (optional)
- Strap-on flotation devices (optional)
- Crush pads (Aluminum honeycomb optional)
- ARGOS transmitter and strobe
- Estimated system cost: $24,155
- Estimated system weight:

  224 kg without options, 291 kg with options

Cost & Weight Breakdown

	Weight, kg	Cost
Parachute System	218	$14,070
Shock Attenuator (opt)	16	$5,500
Land Impact Attenuator	2.3	$180
Water Recovery (opt)	51	$200
Location Aids	3.3	$4,205
TOTAL	291	$24,155